AN INVESTIGATION INTO THE FEASIBILITY OF USING RISK ASSESSMENT METHODOLOGY FOR LICENSING EXPLOSIVES HANDLING PORTS

R. MERRIFIELD

Health and Safety Executive
Magdalen House
Stanley Precinct, Bootle
Merseyside L20 3QZ
United Kingdom

P. A. MORETON

SRD of AEA Technology
Wigshaw Lane
Culcheth, Cheshire
WA3 4NE
United Kingdom

INTRODUCTION

The system of control imposed on explosives movements through ports in Great Britain is based on the well established principle of quantity distances, ie restrictions are placed on the types and quantities of explosives that may be moved so as to ensure limited consequences in the event of an accident. Explosives limits for individual ports are set out in formal licenses issued by the UK Health and Safety Executive (HSE). The HSE has recently licensed GB ports under the 1987 'Dangerous Substances in Harbour Areas Regulations' (DSHAR)[1]. In a number of cases building development around ports has resulted in lower license limits than the operators would desire. Thus much interest has been expressed in the possibility of using quantified risk assessment (QRA) for justifying higher limits.

This paper considers one way in which a QRA-based system of ports licensing might be introduced in Great Britain and looks at the advantages and disadvantages of such a move.

HOW MIGHT QRA BE INTRODUCED?

The Control of Industrial Major Accident Hazards (CIMAH) Regulations [2] requires safety cases to be prepared for certain installations in the UK where large quantities of flammable and toxic substances are handled (explosives installations are currently excluded from these regulations). Regulation 7 of CIMAH requires a person in control of a 'top-tier' industrial activity to submit to the HSE a written safety report. Such a report is to provide information about the dangerous substances, the installation, the management system, potential major accidents and describe the measures taken to prevent, control or minimise the consequences of any major accident. Although not a mandatory requirement, the use of QRA in support of safety cases is now well established in the UK. It is suggested that a QRA-based system of ports licensing could operate on a similar principle: ie operators could apply to HSE for higher license limits than those currently granted and justify those higher limits by the

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preparation of a safety case, of which a QRA would be a major component. In practice the application of a risk-based approach to licensing may lead to real safety improvements through greater operator awareness of risk generating activities. The HSE would subsequently need to evaluate the safety case submitted by the applicant and, if this were then to be included as part of the draft license, account would have to be taken of public comment before the license could be issued.

A precedent for such a system was in fact set as far back as the early 1980s. At this time QRA was used to provide a basis for essentially a political decision to be made, allowing higher limits at one port where there had been a particularly difficult encroachment problem (the port was not subject to DSHAR at that time). The QRA was undertaken at the operator's expense - though the resources required by the HSE in evaluating the operator's report were considerable. This immediately highlights one disadvantage of QRA: it can be a costly technique. The high cost arises from the detailed nature of the analysis that may be required to be undertaken in an assessment. The extent of analysis that would be required in a QRA undertaken in support of an explosives license is discussed in the following section of this paper, together with details of the information that would need to be set out in the applicants report

WHAT INFORMATION SHOULD BE CONTAINED IN A QRA-BASED APPLICATION FOR AN EXPLOSIVES LICENSE?

It is would be essential for the applicant's written report to contain sufficient information to enable structured evaluation to be undertaken by the HSE. The information requirements can be grouped under four headings:-

1 Information relating to the dangerous materials

2 Information relating to the site

3 Information relating to management systems

4 Information relating to the potential major accidents

The information provided under headings 1, 2 and 3 would allow a complete description to be built up of the procedures by which the operator would move explosives through the port, as well as enable those factors to be identified which would bear on the risk of the operation; such information would provide essential background detail to the QRA. The information provided under heading 4 should be sufficiently detailed to allow the HSE to undertake structured evaluation of the method employed by the operator to estimate levels of risk.

1 Information relating to the dangerous materials

The applicant should specify:-

a. For each vehicle carrying explosives into or out of the port, the names of the explosives substances/articles carried, together with methods of packing, Hazard Classification Codes and the net explosives quantity (NEQ) of each type of substance/article in the load.

b. For each explosives ship berthing at the port, the same information as that outlined in a.

c. The number of ships per year on which explosives are to be loaded - and from which explosives are to be off-loaded.

The above information would be required to help establish both the likelihood of occurrence of an explosives accident (which would in part be a function of the types and quantities of explosives handled) and the consequences of an explosives accident (which would in part be a function of NEQ).

d. The names and quantities of any other dangerous substances which may be present at the port at the same time as explosives. The hazards which these other substances pose should be mentioned.

This last point is important as a full assessment of the risks from the handling explosives in ports must take account of possible "domino effects" arising from potential interaction between explosives and other types of dangerous commodities.

2 Information relating to the site

a. A map of the port and its surrounding area to a scale large enough to show any features that may be significant in the assessment of the hazard or risk associated with the movement of explosives through the port. The map should show the location of the port and its relationship to local features such as:-

(i) residential areas;

(ii) premises where evacuation would prove difficult, eg schools, hospitals, prisons, old peoples homes and sheltered accommodation etc;

(iii) industrial and commercial premises;

(iv) other hazardous installations;

(v) transport features, eg major roads and railways;

(vi) recreational areas;

(vii) vulnerable features of the environment, eg buildings of vulnerable construction.

In the case of GB ports, an Ordnance Survey map of scale 1 to 10 000 should provide the necessary detail. The most up-to-date map available should be used and any recent changes of significance should be marked. In those cases where there are many features in the vicinity of the port for which information is required, the use of a tabular form referring to points marked on the map may be appropriate.

b. A scaled plan of the port should be provided to show:-

(i) the route through the port to be taken by explosives vehicles;

(ii) the locations in the port where explosives vehicles might be parked;

(iii) the locations in the port where explosives might be transferred between vehicles (eg between road vehicle and straddle carrier);

(iv) the locations in the port where explosives might be temporarily stored, including the locations where explosives may be moved in the event of an emergency;

(v) the locations in the port where explosives are to be transferred from ship to shore or *vice versa*;

(vi) the locations in the port where other dangerous goods might be present, including the types of goods and an estimate of the quantities present;

(vii) the locations of people within the assessment area.

For this purpose a larger scale map would be necessary, as would a specific annotation to show the required features.

c. A full account should be given of procedures for moving explosives through the port from the point of entry to the point of departure. The account should specify:-

(i) the modes of transport to be used - road vehicle, tractor, straddle carrier, rail vehicle etc;

(ii) the quantity and nature of explosives transported on each vehicle;

(iii) the number of vehicles to be moved through the port, and whether these are to be moved separately or in convoys;

(iv) the type of any inter-modal transfer;

(v) the ship to shore (or shore to ship) mode of transfer - roll-on roll-off (RoRo), container lift, lightering, break-bulk handling;

(vi) the procedures to be followed in an emergency, including the procedures to be followed in the event of an explosives load being suspected of being in an unsafe condition.

d. An estimate of the number of persons on site and how they are distributed throughout the port. As well as port employees estimates should be made of visitors, including delivery staff, clients, customers and contractors.

All of this information is vital to the analysis as clearly accident probabilities will in part be a function of the types of handling procedures employed in the port, and the consequences of explosives accidents will in part be a function of the population distribution in and around the port.

3 Information relating to Management Systems

a. A full account should be given of systems for monitoring the movement of explosives through the port and for controlling the safe operation of these movements. The account should specify:-

(i) the personnel responsible for logging the arrival of explosives into the port;

(ii) the personnel responsible for issuing directions/instructions to drivers of explosives vehicles;

(iii) the personnel responsible for locating explosives vehicles in the event of an emergency; in addition information is needed on how to recognise, and the procedures to be followed in the event of, an emergency.

It would be important for the applicant to specify clearly the conditions and procedures under which explosives would be moved through the port. Any license granted to the port operator would only be valid for the conditions and procedures specified in the application - as clearly any changes in conditions and procedures could have some bearing on accident probabilities and consequences. It is suggested that the license would relate to the operating conditions specified in the application - and indeed would fix these conditions by specific reference to the application.

4 Information relating to the Potential Major Accidents

The applicant's safety case in covering items 1, 2 and 3 above would have identified the potential for the consequences of accidents arising from the handling of explosives. This is a necessary stage but by itself unlikely to be sufficient demonstration that it is reasonable, on safety grounds, to increase the license limits which are based primarily on a consequence based assessment. It can be argued that any increase in license limits constitutes an increase in risk. It is therefore necessary to make a convincing argument that the risk increment is overall or on balance negligible, taking account of the risk exposure of the workforce and public. It may also be relevant to compare a risk increment with some corresponding benefit in order to put it into a broader context.

As a result it is clear that the magnitude of the risk has to be estimated in order to make such an argument. Therefore, the information in items 1, 2 and 3 must be supplemented by formal and quantified consideration of potential major accidents.

The applicant's written submission in support of a higher license limit therefore would need to detail the work undertaken for each of the four stages that comprise the classical form of the QRA procedure:

Accident identification analysis - in which potential causes of explosives accidents in ports would be identified.

Accident frequency analysis - in which estimates would be derived for the potential frequency of occurrence of the identified accidents.

Accident consequence analysis - in which an assessment would be made for the consequences which may be expected from the occurrence of explosives accidents.

Risk analysis - in which the results of the above three stages would be combined to produce estimates for individual and societal risk. In the present context individual risk would be expressed as the annual probability for a specified person being killed as a result of there being an explosives accident within a port, while societal risk would express the chance of such an accident causing a number of fatalities.

It is beyond the scope of the present paper to describe the methods and techniques by which each of the above four stages might be accomplished. Descriptions of appropriate methods of analysis can be found in a recently published report on the risks from the transportation of dangerous goods (including explosives) in the UK.[3] As noted previously, it is likely that considerable effort will be required to undertake the analysis.

It is suggested that the operator should consider two broad categories of accidental initiation of explosives material:-

a. Initiation caused by accidents imparting high levels of energetic stimuli to explosives, eg crane failures, vehicle collisions and fires, ship fires etc.

b. Initiation brought about by the presence of unsafe items in explosives loads. This type of initiation may occur without there being any precursor accident of the type mentioned above.

An important factor that will need to be addressed in any reasonable attempt at quantification of the potential frequency of occurrence of explosives events in ports is quantification of the conditional probability that an explosives item would initiate given the occurrence of an accident of the type listed in a. It is not certain that there are currently sufficient data available to allow objective quantification of probability values for all different types of explosives items given the occurrence of the different types of foreseeable port accidents. There may be a need for fundamental research to be undertaken to clarify areas of uncertainty; it would certainly be desirable for trials to be undertaken to generate objective values for parameters, rather than for too much reliance to be placed on expert judgement.

In carrying out a consequence analysis to determine the numbers of casualties that may be expected from accidental initiations of explosives materials, it is suggested that the applicant should consider the effects of blast, fragments and heat. Ideally, the explosion effects models used by the applicant would take account of the effects of shielding provided by structural features typically found in ports, such as container stacks, and would also be sensitive to buildings of different types of construction. However, if the applicant does not have access to such detailed explosion effects models, it would be important for him to use models which are known to produce a conservative output, ie the analysis should overstate rather than understate potential numbers of casualties.

Finally the HSE will need to form some judgement on the tolerability of the risk levels estimated by the applicant. This may not be a problem in the case of individual risk for which there are some fairly well established criteria in the UK [4]: these are 10^{-3} and 10^{-4} per year for the risk of death to members of a workforce and the general public respectively; an individual risk that exceeded the appropriate value would be regarded as unacceptable. At the other end of the scale a risk below 10^{-7} per year could be regarded as negligible. Levels of individual risk falling between these boundaries would not normally be regarded as intolerable but would be required to be reduced to a level "as low as reasonably practicable". However, numerical criteria can only be used to guide decision makers; it is unlikely that such criteria will become enshrined in legislation. The criteria discussed apply to people already at risk from hazardous installations; different criteria may well apply to the introduction of new risks or new populations. Cost-benefit analysis would be required to determine which risk reduction measures might be regarded as reasonably practicable.

The application of numerical acceptance criteria to societal risk remains to be fully resolved in the UK, though some progress has recently been made[3]. It is beyond the scope of this paper to enter into a discussion on the difficulties encountered in attempts at defining societal risk criteria for activities involving explosives, though clearly such criteria will be needed if a risk-based approach to explosives licensing is to be introduced. It is expected that criteria for operations involving explosives will be considered further during the course of a study recently commenced by the Health and Safety Commission's Advisory Committee on Dangerous Substances into the risks from the handling of explosives in ports.

WHAT ARE THE ADVANTAGES OF THE QRA APPROACH?

The present QD approach to licensing is primarily one of hazard control, ie it effectively limits the consequences of potential accidents (which are perceived to have a low probability of occurrence). The main drawback of this approach is that in some situations it may, at considerable economic cost, do no more than safeguard small numbers of people against an event that is very unlikely to happen. This may be particularly true in the case of any port handling only insensitive explosives; the present system does not discriminate between sensitive and insensitive explosives substances. A QRA-based approach to licensing would essentially differ from the QD approach in that it would set explosives limits based on risk rather than just the consequences to be expected from explosives accidents. In other words the license would take account of the likelihood of an explosives accident occurring as well as the numbers of fatalities expected from such an accident. The major advantage to the port operator is likely to be higher limits for those explosives which are relatively insensitive to energetic stimuli - ie because of the low expected initiation frequency. A QRA-based approach to licensing would also offer a number of more general advantages, including:-

a. General increase in awareness by port operators of risk-generating activities.

b. Identification of high risk operations with scope for safety improvements through site specific measures.

c. Better understanding of risks from potential interactions of explosives with other types of hazardous cargoes in the port.

d. Identification of significant risks for particular modes of handling (eg type of lifting crane/handling operation) with possible long term solutions and subsequent reductions in risk.

e. Scope for higher explosives limits when specific conditions prevail.

WHAT ARE THE DISADVANTAGES OF THE QRA APPROACH?

There are a number of potential problems associated with QRA-based approaches to licensing. These problems can be conveniently summarised under two headings: technical shortcomings and administrative drawbacks. The major technical shortcomings are:-

a. The uncertainty inherent in the results of the QRA process. This uncertainty stems from many sources, including doubts about whether all potentially significant causes of accidents have been identified, questions over the appropriateness of data used to estimate accident probabilities and the inaccuracies of models used to predict the consequences of accidents (the same inaccuracies exist in any assessment based on the QD approach). In many cases probability estimates need to be derived for accidents for which there is little or no historical experience, and in such cases analysis is required of all possible causes of the accidents in question - some of which can be extremely complex in nature - and probability estimates necessarily synthesised using "near miss" data and expert opinion.

b. The assessment of human error presents particular difficulties. It is important that human error be taken into account as a potential cause of accidents if the results of a QRA are to be complete. The HSE has noted that human error may be considered implicitly or explicitly. In the former case overall accident rates would be used in the analysis, the assumption being that these rates have been derived from data for all causes of accidents, including human error. In the latter case a separate analysis would be made of the potential causes of human failure. The implicit approach produces risk estimates relating to an average level of human error; but the quality of safety management at ports may vary. This raises the question of whether adjustment factors should be applied to accident rates to reflect the quality of safety management. The

HSE's present view is that any allowance for good management should only be applied, if at all, within narrow limits[5].

c. Different risk analysts may produce different estimates of risk for the same port, reflecting different depths of analysis undertaken and, perhaps, different levels of knowledge and expertise among the risk analysts. Clearly it could be of mutual benefit for the industry to agree with the HSE an acceptable methodology. The establishment of an agreed methodology would most likely encourage a move towards the use of QRA in the field of explosives, but may not sit comfortably with an overall intent to introduce a goal setting approach to safety as distinct from one which relies on prescription, whether mutually agreed or otherwise.

The major administrative drawbacks are:

d. Compared to the present QD system of licensing, a QRA-based system would be time-consuming and consequently costly. It is likely that considerable expertise and effort would be required to prepare and to evaluate an application submitted by a port operator; further effort would then be required to issue the license, which would need to specify clearly (via reference to the applicant's QRA report) the precise site-specific operating conditions under which explosives are to be moved through the port.

e. Due to the sensitivity of risk levels to changes both on and off site, it is further considered that the license would need to state clearly when changes in operating conditions, procedures and developments in the vicinity of the port would be of such significance as to require further assessment to be undertaken.

f. It may be necessary to establish new consultation zones based on risk contours; an increase in the area of the consultation zone around the port may result in increased numbers of consultations.

g. Subsequent encroachment or changes in operational circumstances could result in relatively frequent reassessments and amendments to ports licenses.

h. Port operators may have difficulty in understanding the terms of a QRA-based license and the factors calling for reassessment. There may thus be a requirement for frequent inspections/safety audits to ensure compliance with the conditions of the license.

i. All of this has cost implications. Under the existing system charges are made for an inspector's time against the cost of the license; these costs would clearly increase for QRA-based licenses.

SUMMARY

The system of ports explosives licensing presently employed in Great Britain is based primarily on hazard limitation, ie restrictions are placed on the quantities of different types of explosives that may be moved through ports so as to ensure limited consequences in the event of an accident. The use of QRA in support of safety cases for installations where large quantities of flammable and toxic materials are handled is now well established in the UK.

This paper has outlined one way in which a risk-based approach to ports explosives licensing could be introduced. The advantage of such a system for port operators is likely to be higher license limits for those explosives which are relatively insensitive to energetic stimuli; it is also likely that such a system would lead to a greater awareness of risk generating activities within ports. However, there are also a number of both technical and administrative drawbacks to such a system. In the UK it remains to be decided whether the advantages of a risk-based approach to licensing are sufficient to outweigh the disadvantages. The final decision on such license applications would be socio-political, based on the technical considerations.

DISCLAIMER

Opinions expressed are those of the authors and should not be considered as statements of HSE policy

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